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ABSTRACT

Forced-choice items, investigating the performance of 80 undergraduates on verbal classification and verbal analogy, were sequentially presented, allowing independent estimates of the accuracy of four principle component processes: inference, application, recognition, and distraction. Within-task performance showed substantial individual variation and the cross-task correlation was highly significant. Individual differences in forced-choice analogy performance were a function of accuracy of inference and application processes and recognition during option processing. Individual differences in classification performance were accounted for by inference accuracy and both recognition and distraction during option processing. Analogy appears to demand an application process which is important for successful solution of an item but which is not required in classification. While the two tasks share common processes there appear to be differences in the relative importance of these processes in discriminating among skilled and less-skilled individuals. In particular, the alternative choices appear to be much more important in classification since they frequently serve to remove ambiguity about the specifics of the rule. The components of option processing and the skill differences in inference that discriminate among adults are contrasted with inference accuracy and the likelihood of distraction components that discriminate among children. (Author/PN)

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Multitask Assessment of Inductive Reasoning Skill

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Abstract

This study investigated the performance of 80 undergraduates on verbal classification and verbal analogy forced-choice tasks. Items were sequentially presented allowing independent estimates of the accuracy of four principle component processes: inference, application, recognition, and distraction. Within task performance showed substantial individual variation and the cross task correlation was highly significant. Individual differences in forced-choice analogy performance were a function of accuracy of inference and application processes and recognition during option processing. Individual differences in classification performance were accounted for by inference accuracy and both recognition and distraction during option processing. Although the two tasks share common components of processing, the process outcome measures were differentially weighted in each task. The results for adults were contrasted with previous developmental findings on components of inductive reasoning.

Multitask Assessment of Inductive Reasoning Skill

David Alderton, Susan R. Goldman and James W. Pellegrino

Inductive reasoning is an important aspect of the psychometric assessment of intelligence and aptitude. Common induction problems found on standardized tests include series completion, analogy and classification. All require the individual to induce a rule (or relationship) among a set of problem elements and then select an item consistent with the rule.

Attention has shifted away from the traditional psychometric scaling of performance on induction problems. Current emphasis involves specifying the cognitive processes that underly task performance and individual differences. Sternberg (1977) proposed a process theory of analogical reasoning that has been extended to other induction problems such as classification (Parseghian & Pellegrino, 1980; Pellegrino & Goldman, in press). The theory also provides a basis for exploring the nature of individual differences in inductive reasoning. As shown in Figure 1, the general theory specifies an ordered series of component processes. The first pair of terms in an analogy must be encoded and a relational rule is inferred. The third term is then encoded and the rule applied to generate a candidate completion term. Once application has been completed, the alternative choices are evaluated and the best choice is selected.

Similar processes are required for solving a classification problem, this is shown in Figure 1. The three stem terms must be encoded and a relationship is inferred. This relationship is frequently a superordinate for a large semantic domain with many candidate exemplars. Finally, the individual must evaluate the alternative choices for consistency with the inferred rule and select the best one. A potential difference between classification and analogy is whether application is necessary in classification prior to evaluating the alternatives. Also, application of the

inferred rule may involve different psychological processes in analogy and classification. In analogy it involves applying a specific relationship to an item from a new semantic domain. In classification it involves generating a new instance consistent with the general rule.

Insert Figure 1 about here

Both analogy and classification performance depend on accurate execution of two sets of processes. The first set involves encoding, inference and application processes associated with the item stem. The second set involves response selection processes associated with evaluating the alternative set. There are three major ways in which stem and alternative set processing may be related. These possibilities are shown in Table 1. In the simplest case, encoding, inference and application have been successfully executed. Each of the alternatives is evaluated for consistency with the semantics of the item stem and the correct choice is selected. The second case also involves accurate stem processing. However, a highly salient but inappropriate relationship exists between an incorrect alternative and one or more of the stem terms. This provides a source of distraction and leads to a response selection error. The developmental literature suggests that this frequently occurs for children. The third possibility is that stem processing is incorrect. However, while evaluating each alternative, the individual recognizes the correct rule. Thus, the alternatives provide a vehicle for additional semantic processing that leads to correct solution.

The different outcomes for stem and option processing apply to each analogy or classification item solved. By considering performance over an

entire set of items, a general prediction equation can be derived for overall forced-choice performance. The prediction equation for analogy and classification performance is also shown in Table 1. The equation represents the separate contributions of inference, application, recognition, distraction and guessing. If the probabilities of recognition and distraction are zero, then forced-choice accuracy is predicted by stem processing accuracy plus guessing. This equation is appropriate for group and individual subject data. Its application requires independent estimates of each probability. The latter can be obtained through a structured sequential item presentation.

Insert Table 1 about here

The separate performance components are possible sources of skill differences in analogy and classification problem solving. Several important issues can be addressed when the same individuals are tested on both analogy and classification tasks. The first issue concerns the contribution of each process component in determining individual differences within each task. The second issue concerns similarities and differences between adult and child performance on each task. The third issue concerns the relationships between common process outcome measures for the two induction tasks.

The present research addressed these issues. We examined the performance of a large sample of young adults on both induction tasks. Eighty undergraduates participated in the study. They were tested in small groups (from 1-5 members) and participated in two sessions separated by several days. A session consisted of either a verbal analogy or classification task; task type and item presentation were counterbalanced across subjects.

We will first consider performance in the analogy task. Table 2 contains a summary of the major results. Results are shown for the entire sample of subjects as well as the upper and lower quartiles. Overall forced-choice accuracy was 74%, the upper and lower quartiles showed a 35% difference in accuracy. Table 2 also shows the performance levels for stem and option processing components. Accuracy of stem processing was 50% with a 33% difference between quartiles. Of particular interest are data for the two measures of option processing. The overall probability of recognizing a correct solution when stem processing was incorrect was .33 and there was a three-fold difference in recognition between the upper and lower quartiles. In contrast, the probability of distraction was extremely low and this was true for all subjects. In fact, 59 of the 80 adults showed a zero likelihood of being distracted by the option set when prior stem processing was correct. The last column of Table 2 shows the simple correlations between each performance measure and overall forced-choice accuracy. These data verify that inference, application and recognition are all important contributors to individual differences in analogy solution. This conclusion is confirmed by the results of a multiple regression analysis which are also shown in Table 2. The combined inference and application measure and the recognition measure were both significant predictors of overall forced-choice accuracy and had approximately equivalent beta weights.

Insert Table 2 about here

It was possible to conduct a more detailed analysis of performance for 40 of the subjects. They solved the items under a presentation format that

yielded separate estimates of inference and application. The multiple regression results for this subgroup are also shown in Table 2. Both inference and application were significant contributors in the prediction of forced-choice accuracy and their combined contribution approximates the value obtained for the entire sample of subjects.

The adult data can be contrasted with similar data obtained for third and fifth grade children by Goldman, Pellegrino, Parseghian and Sallis (1982). This study also showed that both stem and option processing were significant factors in predicting individual differences in the forced-choice accuracy of children. The major difference, however, was that children showed a much greater susceptibility to distraction effects during option processing. While the adults in the present study showed only a .04 probability of distraction, the corresponding probabilities for third and fifth grade children were .36 and .27, respectively. The distraction component was a major contributor in the multiple regression analysis of individual differences in children's performance.

Table 3 shows a similar breakdown of the data for adult performance on the classification task. Overall forced-choice accuracy was 72% and the upper and lower quartiles showed a 37% difference in accuracy. All of the measures of stem and option processing showed substantial differences between the upper and lower quartiles. Of particular interest is the fact that the upper quartile subjects continue to show a relatively low probability of distraction. However, distraction is now substantial in the performance of the lower quartile subjects. The correlational results shown in Table 3 confirm the fact that each performance component is significantly related to individual differences in forced-choice accuracy. However, the most important components of processing are those associated

with evaluating the options. This is indicated by the results of the multiple regression analysis. In fact, distraction is the most highly weighted predictor of performance differences.

Insert Table 3 about here

The reduced importance of the stem processing measure in the multiple regression analysis may be a function of including the application component. As noted earlier, application may not be essential in solving classification items and its inclusion in the stem processing measure may be suppressing a significant individual contribution of inference. It was possible to test this assumption for a subgroup of 40 subjects. They provided separate data for the inference and application components. The results of the multiple regression for this subgroup are also shown in Table 3. The data clearly show that application makes no contribution to predicting individual differences in forced-choice accuracy. Inference is a significant predictor but its contribution is considerably less than recognition and distraction. The beta weights for the latter two measures are virtually identical to those obtained for the entire sample of 80 subjects.

The classification data for the present adult sample can be contrasted with similar data obtained by Parseghian and Pellegrino (1980) for a sample of third and fifth grade children. Individual differences among children were observed in both inference accuracy and the likelihood of distraction. The children's data indicated that the most important predictor of individual differences in classification accuracy was the inference component. As shown in Table 3, skill differences were observed among adults in inference.

However, the components of option processing were more critical in differentiating among adults. These results suggest a potential difference between adults and children in their approach to dealing with verbal classification items. Adults may recognize the multiple possible relations that could define the rule for the item and therefore rely more on the alternatives to constrain inference and guide solution. Adults differ substantially in the ability to effectively use the option set to clarify the semantics of the item. These differences go beyond initial differences in inference.

The present data also allow consideration of similarities and differences between performance in analogy and classification. First, we should point out that overall performance on the two tasks was highly related. There was a 90% overlap with respect to the individuals in the lower quartile of both tasks and a 65% overlap for the upper quartile. Table 4 shows that the correlation between forced-choice performance for the two tasks was .72. We also examined the relationship between corresponding measures for the two tasks. These data are also shown in Table 4. As can be seen in the table, the inference and recognition measures were significantly correlated across the two tasks. These data support the general assumption that common components of processing are being measured in both tasks. Application, however, was not correlated and this supports the hypothesis that application does not represent the same psychological processes in analogy and classification. The low correlation for distraction reflects attenuation of this measure in the analogy task.

Insert Table 4 about here

The data in Table 4 clearly show that individual differences in the two induction tasks were correlated. However, the multiple regression data shown earlier, indicate that there are also important differences between analogy and classification. Option processing is of primary importance in differentiating among adults in the classification task. In contrast, both stem and option processing are important in the analogy task. This pattern is consistent with apparent differences in the psychological demands of the two tasks. Stem processing in the analogy task is more complex and constrained than in the classification task. The stem of the analogy item greatly restricts the range of possible completions. Evaluation of the alternatives typically involves little ambiguity. Consistent with this interpretation is the result that appropriate stem processing seldom led to distraction problems in selecting among the analogy choices. In contrast, the stem of a classification item usually permits several possible rules and a broad range of possible completions. Refining the semantics of the item appears to be much more dependent on the set of possible choices. In support of this hypothesis is the fact that recognition scores were higher in the classification task. Additionally, individuals often appeared to have an appropriate rule for a classification item but suffered distraction effects when required to select among two or more competing choices.

The results of our research can be briefly summarized as follows. First, both analogy and classification assess certain common components of processing. Individuals show consistency across tasks in the success of executing these processes. Analogy also appears to demand an application process which is important for successful solution of an item but which is not required in classification. While the two tasks share common processes there appear to be differences in the relative importance of these processes in discriminating among skilled and less-skilled individuals. In

particular, the alternative choices appear to be much more important in classification since they frequently serve to remove ambiguity about the specifics of the rule. A final point is that the components of performance that discriminate among adults are not necessarily the same as those that discriminate among children.

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Table 1

Relationsip Between Stem and Option Processing

	Stem Processing Outcome	Option Processing Outcome	Overall Accuracy
I.	Accurate execution of Encoding, Inference and Application	Accurate execution of response selection	Correct
II.	Accurate execution of Encoding, Inference and Application	Distraction during response selection	Incorrect
III.	Inaccurate execution of Encoding, Inference and/or Application	Recognition of appropriate rule during response selection (or successful guessing)	Correct

Prediction Equation

$$P_{FC} = \underbrace{P_{Inf}P_{App}}_{\text{Stem Processing}} + \underbrace{R_{Rec}(1 - P_I P_A) + 1/K\{1 - [P_I P_A + P_R(1 - P_I P_A)]\} - P_{Dist}P_I P_A}_{\text{Option Processing}}$$

Table 2

Analogy Performance Measures

	Group Mean (N = 80)	Upper Quartile (N = 20)	Lower Quartile (N = 20)	Correlation with FC Accuracy
Forced-Choice Accuracy	.74	.90	.55	--
Stem Processing				
Inference x Application	.50	.67	.34	.80
Option Processing				
Recognition	.33	.52	.14	.83
Distraction	.04	.01	.09	-.44

Multiple Regression (N = 80)

R^2 = .88

Predictor	β	F
Inf x Appl	.44	106.72
Recognition	.48	156.03

Multiple Regression (N = 40)

R^2 = .87

Predictor	β	F
Inference	.27	16.81
Application	.14	7.09
Recognition	.56	101.64

Table 3

Classification Performance Measures

	Group Mean (N = 80)	Upper Quartile (N = 20)	Lower Quartile (N = 20)	Correlation with FC Accuracy
Forced-Choice Accuracy	.72	.87	.50	--
Stem Processing				
Inference x Application	.61	.71	.43	.68
Option Processing				
Recognition	.44	.56	.22	.72
Distraction	.22	.08	.43	-.80

Multiple Regression (N = 80)

R^2 = .91

Predictor	β	F
Inf x Appl	.09	3.50
Recognition	.37	162.25
Distraction	-.56	224.53

Multiple Regression (N = 40)

R^2 = .91

Predictor	β	F
Inference	.10	3.97
Application	.00	.00
Recognition	.39	101.13
Distraction	-.58	82.98

Table 4

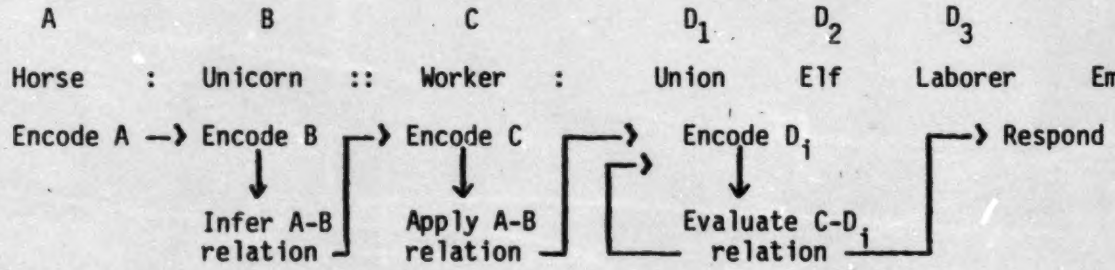
Correlations Between Analogy and Classification Performance Measures

Measure	Simple r
Forced-Choice Accuracy (N = 80)	.72**
Inference (N = 40)	.47*
Recognition (N = 80)	.42**
Application (N = 40)	.31
Distraction (N = 80)	.16

*p < .005 **p < .001

Figure 1

Analogy Solution



Classification Solution